RAPID BIOASSESSMENT OF THE

RHODES CREEK WATERSHED

USING BENTHIC MACROINVERTEBRATES

October 1996

for the Soil and Water Conservation District of
Morgan County, Indiana

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EXECUTIVE SUMMARY

A rapid bioassessment technique was used to determine the degree of biological impairment present in Rhodes Creek in Morgan County, Indiana prior to implementation of various land treatments in the watershed. The benthic communities of three sites and a nearby reference stream were sampled during October 1996 to provide information on "before treatment" conditions.

The upper section of Rhodes Creek had a benthic community indicative of "moderately impaired" conditions, while the communities of the lower sections of the stream were indicative of "slightly impaired" conditions. All sites were adversely affected by reduced aquatic habitat and water quality problems. Some of the study sites were characterized by higher proportions of "sediment-tolerant" animals and fewer kinds of "sediment-intolerant" animals than the regional reference stream. This indicates that sediment loading may be too high at these sites. There were also signs of excessive nutrient inputs and inputs of oxygen-demanding pollutants (e.g. sewage).

A similar study had been conducted in July 1996. Water quality has improved at two of the three sites (middle and lower Rhodes Creek) since July. The biggest change occurred in lower Rhodes Creek, where the biotic index score increased from 6 (indicating severe impairment) to 26 (indicating only slight impairment). The reason for this large improvement in just a few months is not known but is probably not related to changes in agricultural practices in the watershed.

Recommendations for continued improvement of water quality in the Rhodes Creek watershed include protection of the vegetative border along the stream, discouraging channelization and direct access to the stream by livestock, implementation of land treatments to reduce nutrient and sediment inputs, and continued monitoring to document improvements over time. Improved conditions will be evident by a decrease in sediment-tolerant animals and an increase in the numbers and kinds of animals which require high water quality. An investigation of sewage treatment practices at homes within the watershed is also warrented.

INTRODUCTION

This study was conducted to measure the "biological integrity" of Rhodes Creek in Morgan County, Indiana. Rhodes Creek has been identified by the Soil and Water Conservation District of Morgan County as being adversely affected by agricultural runoff. In addition, the stream is a tributary of the Eel River, which is listed by the Indiana Department of Environmental Management (IDEM) has as having seriously degraded water quality due to nonpoint sources of pollution [1]. Soil conservation plans are being designed by the Morgan County SWCD office to help reduce non-point source problems in the stream. Studies of Rhodes Creek before and after application of land treatments in the watersheds can help determine whether treatments resulted in improved water quality as reflected by a improved aquatic biological communities.

Local Setting

Rhodes Creek has an interesting geography. It is located near the intersection of the "Eastern Corn Belt" and "Interior Pleateau" ecoregions of the Central United States. [2]. The area immediately north of Rhodes Creek is a glacial till plain (it was one of the last areas in Indiana to be occupied by glacial ice), while the area to the immediate south was not glaciated during the most recent Ice Age era. On a local scale, the Rhodes Creek watershed is within 20 kilometers of six different Natural Regions of Indiana [14]. Therefore, the stream has the potential to be influenced by a wide variety of geographic features. The Central Till Plain to the north is is an area with little geographic relief and its soils are typically rich in silt and silty clay loams. To the south, the Interior Plateau presents a more rolling terrain, with soils derived mainly from limestone. Originally, the watershed is thought to have supported an extensive beech-maple-oak forest, but row crop agriculture and livestock grazing are the most common land uses today. The unincorporated town of Lewisville (1990 population of 437) lies in the watershed.

Rhodes Creek is a small "third order" stream with a total drainage area of about 50 square kilometers or 20 square miles [18]. It flows northwestward and joins the larger stream, Mill Creek, which is a tributary of the Eel River. Presently, only a few sections of Rhodes Creek are artificially channelized and most areas retain their natural channel characteristics. Only about 5 to 10% of the watershed is wooded, with most of the remainder being used for agricultural purposes. The upper section of Rhodes Creek is about 20% wooded.

Three Rhodes Creek "study" sites and a "reference" site were chosen for sampling (Fig. 1). The study sites represented the upper, middle and lower parts of Rhodes Creek. The reference site is described in more detail below. A summary of each site and its watershed area is shown below:

Site 1	Rattlesnake Creek @ Cuba Rd. (Owen County, Reference Site)	38 km^2 (15 mi^2)
Site 2	Rhodes Creek near Mill Creek (Lower watershed)	51 km^2 (20 mi^2)
Site 3	Rhodes Creek @ CR 400 N (Middle watershed)	33 km^2 (13 mi^2)
Site 4	Rhodes Creek @ CR 1100 W (Upper watershed)	13 km^2 (8 mi^2)

All samples and water quality measurements reported here were collected on October 31, 1996.

Figure 1.

Generalized location of all sites.

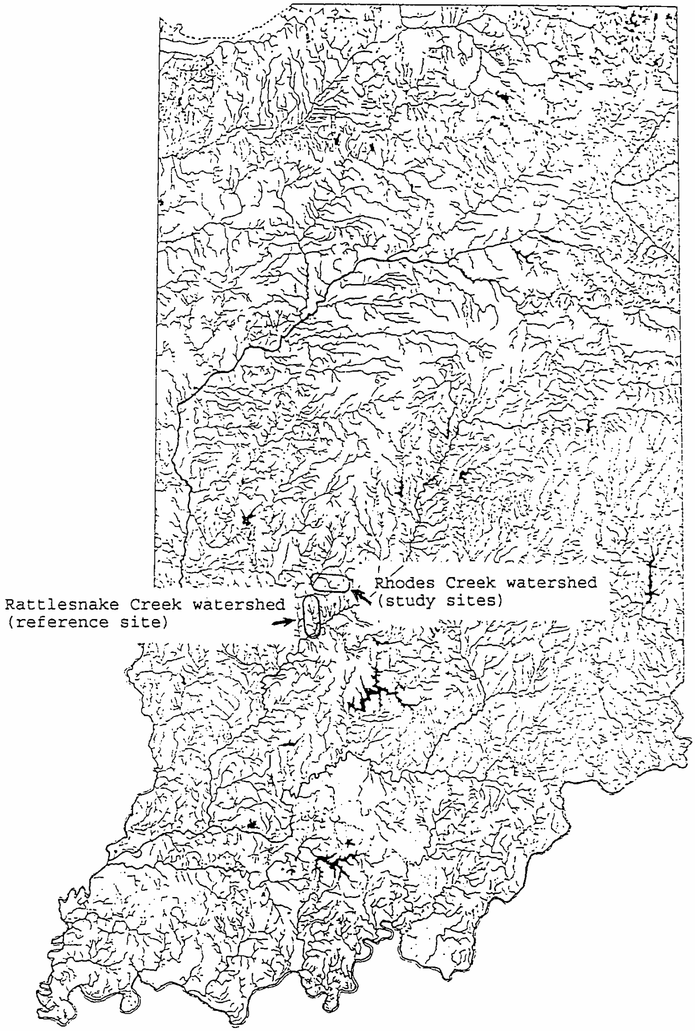
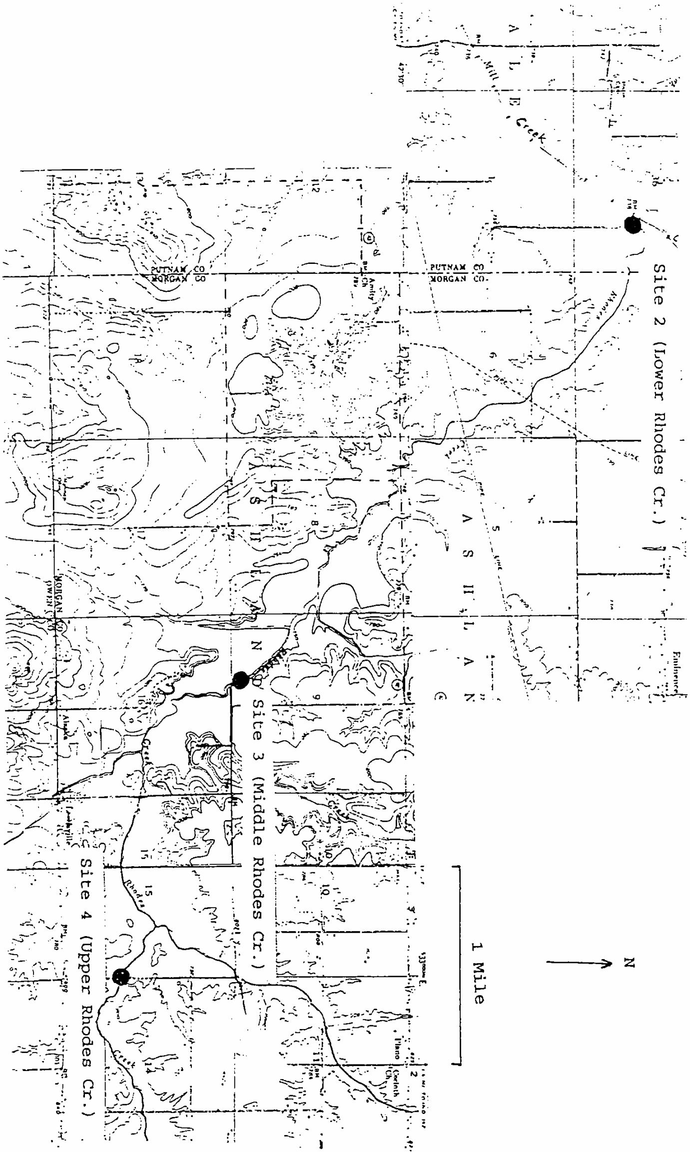


Figure 2.

Locations of study sites on Rhodes Creek



METHODS

Because they are considered to be more sensitive to local conditions and respond relatively rapidly to environmental change [3], benthic (bottom-dwelling) organisms were used to document the biological condition of each stream. The U.S. Environmental Protection Agency (EPA) has recently developed a "rapid bioassessment" protocol [4] which has been shown to produce highly reproducible results that accurately reflect changes in water quality. We used EPA's Protocol III to conduct this study. Protocol III requires a standardized collection technique, a standardized subsampling technique, and identification of at least 100 animals from each site to the genus or species level from both "study sites" and a "reference site."

Reference Site

In the rapid bioassessment technique, the aquatic community of a reference site is compared to that of each study site to determine how much impact has occurred. The reference site should be in the same "ecoregion" as the study sites and be approximately the same size. It should be as pristine as possible, representing the best conditions possible for that area. Rattlesnake Creek in Owen County was chosen as the reference site for this study. Its watershed area at the selected study site is about 38 square kilometers (15 square miles), which is similar to those of the study sites on Rhodes Creek. In addition, it is located less than 25 kilometers (10 miles) south of the study stream and therefore is representative of local conditions. Rattlesnake Creek is known to have excellent aquatic habitat and one of the highest "biotic index values" for fish and macroinvertebrate communities in central Indiana [5,6]. Therefore, its habitat and water quality are probably among the best available within this area.

Habitat Analysis

Habitat analysis was conducted according to Ohio EPA methods [21]. In this technique, various characteristics of a stream and its watershed are assigned numeric values. All assigned values are added together to obtain a "Qualitative Habitat Evaluation Index." The highest value possible with this habitat assessment technique is 100.

Water Chemistry

Water chemistry measurements were made at each study site on the same day that macroinvertebrate samples were collected. Dissolved oxygen was measured by the membrane electrode method. The pH measurements were made with a Cole-Parmer pH probe. Conductivity was measured with a Hanna Instruments meter. Temperature was measured with a mercury thermometer. All instruments were calibrated in the field prior to measurements.

Macroinvertebrate Sample Collection

Samples in this study were collected by kicknet from riffle habitat where current speed was 20-30 cm/sec. Riffles were used because they were the most important benthic habitat present at all study sites. The kicknet was placed immediately downstream from the riffle while the sampler used a hand to dislodge all attached benthic organisms from rocks upstream from the net. The organisms were swept by the current into the kicknet and subsequently transferred to a white pan. Each sample was examined in the field to assure that at least 100 organisms were collected at each site. In addition, each site was sampled for organisms in CPOM (coarse particulate organic matter, usually consisting of leaf packs from fast-current areas). All samples were preserved in the field with 70% ethanol.

Laboratory Analysis

In the laboratory, a 100 organism subsample was prepared from each site by evenly distributing the whole sample in a white, gridded pan. Grids were randomly selected and all organisms within grids were removed until 100 organisms had been selected from the entire sample.

Each animal was identified to the lowest practical taxon (usually genus or species). As each new taxon was identified. a representative specimen was preserved as a "voucher." All voucher specimens have been deposited in the Purdue University Department of Entomology collection.

Quality Assurance

To help assure the quality of the results, a duplicate sample was collected at Site 1. The biological scores of each sample were measured to determine the amount of variability associated with the technique. Ideally, the individual scores of duplicate samples should be within about 10% of the mean score to assure that reproducible results are obtained.

RESULTS

Quality Assurance

The biotic index scores and use impairment categories of Site 1, as determined by duplicate samples, were within 10% of the mean (see Appendix). These indicators show that the bioassessment technique resulted in reproducible and reliable data during this study period.

Aquatic Habitat Analysis

When the Ohio EPA habitat scoring technique was used, the following aquatic habitat values were obtained for each site in the study:

	Score	% of Reference
Rattlesnake Creek (Site 1, Reference)	83	100
Rhodes Creek (Site 2, Lower Watershed)	55	66
Rhodes Creek (Site 3, Middle Watershed)	66	80
Rhodes Creek (Site 4, Upper Watershed)	75	90

The maximum value obtainable by this scoring technique is 100, with higher values indicating better habitat. Sites with lower habitat values normally have lower biotic index values as well.

The scores indicate that the lowest habitat value in this study was at Site 2 (the most downstream segment of Rhodes Creek). Habitat at Site 2 was hampered by a paucity of stable bottom substrate, by a very narrow riparian buffer zone, and by severe bank erosion. Sediment deposition appeared to be heavier at this site than elsewhere in the watershed.

Water Quality Measurements
October 31, 1996

	D.O. mg/l	pH SU	Cond. uS	Temp. (C)
Reference Site 1 Time = 1:50 p.m.	12.8	8.2	270	8.0
Site 2 (Lower Rhodes) Time = 12:20 p.m.	6.9	7.8	380	9.0
Site 3 (Middle Rhodes) Time = 11:00 a.m.	18.4	8.5	350	9.5
Sandy Creek	11.6			
Site 4 (Upper Rhodes) Time = 9:15 a.m.	4.5	7.6	370	7.5
CR 925 W (south trib.)	8.5			
(north trib.)	4.1			
CR 800 W (south trib.)	6.7 (flowing)			
(north trib.)	2.6 (not flowing)			

D.O. = Dissolved Oxygen
Cond. = Conductivity
Temp. = Temperature in Degrees Centigrade

Mussel Observations

No mussel shells or live mussels were observed at any site during this study. There are no historical records of mussels from Rhodes Creek.

Table 1.
Rapid Bioassessment Results - Rhodes Creek
October 1996

	Site #			
	1	2	3	4
Chironomidae (Midges)				
Chironomus spp.				2
Cricotopus bicinctus			33	
Brillia flavifrons			1	
Parametriocnemus lundbecki	1		1	
Diplocladius sp.		16	2	18
Corynoneura sp.		2		
Dicrotendipes nervosus			2	
Endochironomus nigricans	1	2		
Microtendipes caelum	3			
Rheotanytarus exiguus		1	4	1
Thienemannymia gr.	3	15	2	
Simuliidae (Blackflies)	7	5		6
Tipulidae (Craneflies)				
Tipula sp.	3	1	1	3
Plecoptera (Stoneflies)				
Allocapnia spp.		1		57
Ephemeroptera (Mayflies)				
Attenella sp.		1		
Stenonema vicarium	13			
S. femoratum	1		3	
Stenacron interpunctatum		3	4	
Baetis intercalaris		2	1	
B. flavistriga		4		
Isonychia sayi	12			
Tricorythodes sp.			1	
Caenis sp.	1			
Trichoptera (Caddisflies)				
Cheumatopsyche spp.	20		11	4
Hydropsyche betteni	5			
Chimarra obscura	7			
Helicopsyche borealis	1			
Leptoceridae			1	
Rhyacophila sp.				1
Coleoptera (Beetles)				
Dubiraphia vittata		4		
Optioservus sp.	8		2	
Macronychus glabratus		1		
Stenelmis sp.				6

Table 1 (cont.)
Rapid Bioassessment Results

	Site # 1	2	3	4
Megaloptera (Dobsonflies)				
Chauliodes spp.	3			
Odonata (Dragonflies)				
Argia sp.		2		
Calopteryx sp.			1	
Corixidae (Water Boatmen)		3		
Amphipoda (Scuds)				
Gammarus sp.			21	
Isopoda (Aquatic Pillbugs)				
Caecidotea sp.		6		
Lirceus sp.			3	
Gastropoda (Snails)				
Elimia livescens	2			
Ferrissia sp.	1	5		
Physella gyrina	7	5	3	
Fossaria sp.	1		1	
Turbellaria (Planaria)		17	1	
Oligochaeta (Worms)				
Tubificidae		4	1	2
Total	100	100	100	100

Table 2. Data Analysis for 10/96 Samples

METRICS

	Site # 1	2	3	4
# of Genera	19	20	23	10
Biotic Index	5.0	7.5	7.3	4.6
Scrapers/Filterers	0.6	3.2	0.7	0.6
EPT/Chironomids	7.5	0.3	0.5	3.0
% Dominant Taxon	20	36	21	57
EPT Index	7	4	6	3
Community Loss Index	0.0	0.7	0.5	1.6
% Shredders (CPOM)	13	8	0	25

SCORING

	Site # 1	2	3	4
# of Genera	6	6	6	2
Biotic Index	6	2	2	6
Scrapers/Filterers	6	6	6	6
EPT/Chironomids	6	0	0	2
% Dominant Taxon	6	2	6	0
EPT Index	6	0	4	0
Community Loss Index	6	4	6	2
% Shredders (CPOM)	6	6	0	6
TOTAL	48	26	30	24
% of Reference	100	54	63	50
Impairment Category	N	S	S	M

N = NONE S = SLIGHT M = MODERATE

DISCUSSION

Chemical parameters measured at each site indicate that dissolved oxygen (D.O.), pH, temperature, and conductivity fell within acceptable ranges for most forms of aquatic life. D.O. was unusually low in Upper Rhodes Creek (Site 4), so several tributaries were also investigated. Some of these tributaries had D.O. values below the Indiana minimum water quality value of 4 mg/l. The water in these tributaries was not flowing, and the isolated pools contained heavy accumulations of fallen leaves. D.O. was probably reduced in these areas by the rapidly decaying leaves. Therefore, some parts of the upper watershed are naturally susceptible to low D.O. following leaf fall in autumn during especially dry periods.

There was also an unusual change in water chemistry between Sites 2 and 3 (upper and middle Rhodes Creek). Dissolved oxygen and pH increased dramatically in the middle part of the watershed. The most common cause for dissolved oxygen levels well above saturation and pH values greater than 8.5 is intense algal growth caused by nutrient enrichment, especially in areas where there is no shading tree canopy to keep direct sunlight out of the stream. A photo in the Appendix shows an example of an algae bloom in an unshaded section of stream near Site 3.

Downstream from Site 3, dissolved oxygen and pH declined once again. The reason for this decline is unknown but could also be related to increased algal respiration. When algae are present in high numbers but sunlight is excluded (lower Rhodes Creek had a shading canopy over much of the channel), the algae use oxygen rather than produce it and pH declines as the algae produce carbon dioxide instead of oxygen.

A total of 44 macroinvertebrate genera were collected at the four sites. The most commonly collected invertebrates were caddisfly larvae (e.g. Cheumatopsyche sp. at Site 1), midge larvae (e.g. Cricotopus bicinctus, Thienemannymia, or Diplocladius sp. at Sites 2 and 3) and stonefly nymphs (e.g. Allocapnia sp. at Site 4).

Table 2 shows how the aquatic communities at the three Rhodes Creek study sites compared to that of the reference stream. The best possible biotic index score is "48". The table shows that the biotic index values of Rhodes Creek varied from "24" at the most upstream site (site 4) to "30" in the middle part of the watershed (site 2). According to the U.S. EPA scoring guidance, the two lowermost sites on Rhodes Creek were "slightly impacted" while the uppermost site was "moderately impacted."

Figure 3 shows the normal relationship of biotic index scores to habitat values (a linear relationship according to [4]). The figure also shows a range of plus or minus 10% to account for a certain amount of measurement variability. When biotic index values fall outside this range, the site typically has degraded water quality. Figure 3 indicates that all sites had biotic index values below those predicted by their habitat. Therefore, all three sites on Rhodes Creek may be affected by degraded water quality as well as habitat loss. The greatest deviation from the predicted value occurred at Site 4 (Upper Rhodes Creek).

An examination of those metrics showing the greatest difference from the reference stream may provide an important clue about causes of biological impairment. The largest differences at most of Rhodes Creek sites were (1) a decrease in the Scraper/Filterer ratio (the number of "filtering" animals using particulate algae for food increased at the expense of "algae scraping" animals, (2) an increased abundance of a "tolerant" group (midge larvae), (3) a decline in the EPT index value ("intolerant" animals), (4) increasing dominance by a single group and (5) an almost complete absence of "shredder" organisms.

An increase in filtering animals (those which collect and eat small particles collected by filtering) at the expense of scrapers (those which scrape off algae attached to rocks or other hard substrates) is indicative of an increase of "fine particulate organic material" in the water. This is often associated with increased sedimentation. Sometimes, this metric also indicates a change in dominance in the stream from periphyton (algae attached to rocks) to filamentous algae or moss associated with nutrient enrichment [4].

The decline in the number and types of EPT organisms (those which are known to be especially sensitive to environmental changes) and an increased dominance by midge larvae are signs of several kinds of environmental degradation. For example, some studies have shown this metric to be associated with instream toxicity [11]. However, changes in other metrics commonly indicating toxicity problems (e.g. a reduction in the number of taxa) were not observed and few "toxic indicator" organisms were observed at any site. A more likely explanation for this shift in the types of animals present is stress caused by stream sedimentation or nutrient enrichment, often associated with agricultural runoff. Such changes favoring chironomids at the expense of EPT taxa have been observed in other studies [9].

The absence of "shredder" organisms (those which use coarse particulate matter such as leaves for food) is often associated with a lack of tree canopy along a stream (Plafkin, 1989). If their primary food source is lacking, shredder organisms cannot thrive.

Figure 3.
Habitat vs. Biotic Index Scores

Sites falling outside the +10% range are probably affected by degraded water quality

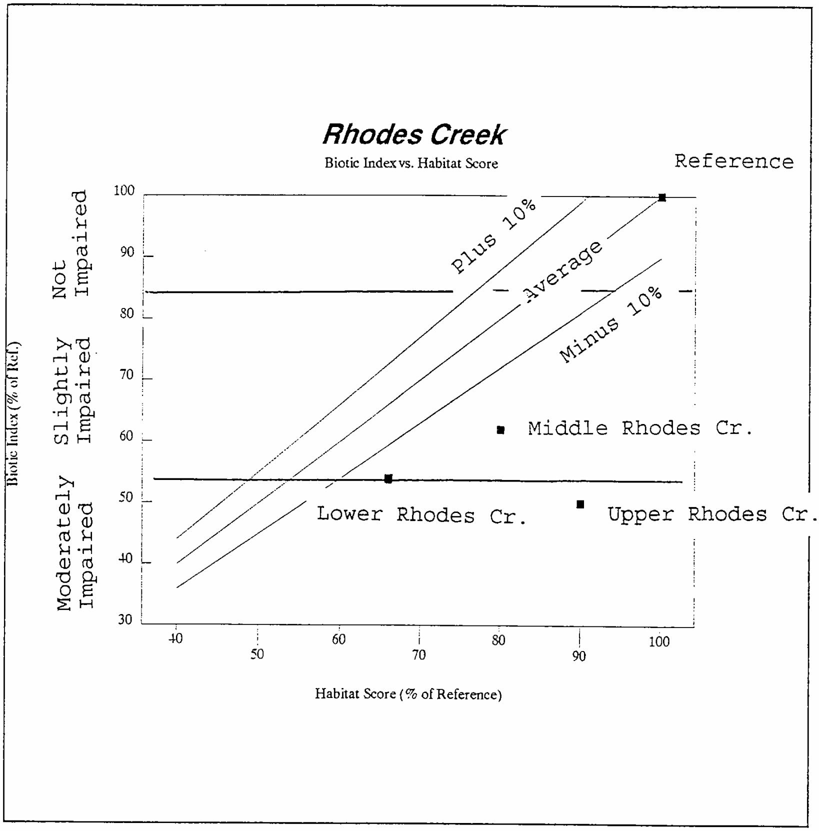


Table 4 shows sediment-tolerance values for many of the commonly collected animals in these streams. Sediment and turbidity-intolerant forms were less abundant in middle and lower Rhodes Creek than in the reference site. These results indicate that excess sedimentation may be a primary water quality problem in some portions of Rhodes Creek. Sedimentation appears to be especially severe in the lower end of the watershed, where sediment-intolerant animals are nearly absent.

It is interesting to note that the Hilsenhoff Biotic Index (HBI) metric, which is highly sensitive to reductions in dissolved oxygen [17], was also higher at the middle and lower Rhodes Creek sites than at the reference stream. This may indicate that, in addition to sedimentation, a significant source of oxygen-demanding pollutants is also contributing to the water quality degradation observed in Rhodes Creek. Measured D.O. at all sites were well within acceptable concentrations during this study, but D.O. could be much lower on occasion.

The unsewered community of Lewisville may be a potential contributor to some of the water quality problems observed. Lewisville is immediately upstream from Site 2, where the unusual D.O. and pH readings were observed. Failing septic tanks concentrated in a small area can leak untreated or partially treated sewage directly into streams. Sewage contains large amounts of nutrients which can contribute to algae blooms. As algae grows, it often produces huge swings in dissolved oxygen, with large amounts during the day and very low levels at night or following a succession of cloudy days.

In summary, sediment accumulation and nutrient enrichment appear to be the most likely cause of water quality impairment in Rhodes Creek. Additional impairment may be due to periodically low dissolved oxygen concentrations, either associated with algae blooms or from an unknown oxygen-demanding pollutant (e.g. sewage).

Table 4. Sediment-Tolerant Species Observed
(References shown in brackets)

Cheumatopsyche sp.	[10]	[9]
Hydropsyche betteni	[9]	
Stenacron interpunctatum	[10]	
Baetis flavistriga	[9]	
Tricorythodes spp.	[10]	
Caenis spp.	[10]	
Macronychus glabratus	[10]	
Chironomus spp.	[7]	
Endochironomus spp.	[10]	
Rheotanytarsus spp.	[10]	
Thienemannymia group	[10]	
Tubificidae	[12]	

October Samples

% of Sediment-Tolerant Organisms at the Reference Site 1		30%
% of Sediment-Tolerant Organisms at the Study Sites		
	Site 2	32%
	Site 3	20%
	Site 4	15%

Sediment-Intolerant Species Observed

Microtendipes spp.	[10]	
Brillia spp.	[10]	
Tipula sp.	[10]	
Helicopsyche borealis	[10]	
Chimarra obscura	[10]	
Stenonema vicarium	[10]	[15]
S. femoratum	[10]	[15]
Plecoptera	[10]	
Gammarus spp.	[21]	

October Samples

% of Sediment-Intolerant Organisms at the Reference Site 1		36%
% of Sediment-Intolerant Organisms at the Study Sites		
	Site 2	2%
	Site 3	28%
	Site 4	60%

Comparison to Other Studies

The benthic macroinvertebrate community of Rhodes Creek was examined in an identical study completed in July 1996. The results and a comparison with the present study are summarized below:

	July Biotic Score	July Impairment Category	Oct. Biotic Score	Oct. Impairment Category
Reference	48	None	48	None
Lower Rhodes Cr.	6	Severe	26	Slight
Middle Rhodes Cr.	14	Moderate	30	Slight
Upper Rhodes Cr.	16	Moderate	24	Moderate

Upper Rhodes Creek had the same degree of impairment during both study periods, while the Middle and Upper Rhodes Creek sites had significantly improved water quality. The biggest difference was in Lower Rhodes Creek, which changed from severely impaired in July to only slightly impaired in October. The reason for this huge improvement in water quality in just a few months is unknown. It is unlikely that changes in agricultural practices in the watershed were responsible, since planned land treatments have not yet been initiated.

The fisheries biologist Shelby Gerking [20] collected fish from Mill Creek immediately upstream from Rhodes Creek in 1942. There were only 11 species present in his collections at this site. Such a low degree of diversity is often indicative of degraded water quality or habitat. In addition, almost all of the fish present were those considered "facultative" or "tolerant" to environmental degradation. This historical record of its aquatic community indicates that Mill Creek near its confluence with Rhodes Creek was probably not in very good condition 50 years ago.

Gammon et al. [5] collected both fish and macroinvertebrates from two sites on the reference stream, Rattlesnake Creek, during 1978-1980. Thirty-seven fish species were present, including many which are common only in high-quality streams with both good habitat and clear, unpolluted water. Likewise, the macroinvertebrate community of Rattlesnake Creek was characteristic of streams with of good habitat and water quality. Certain pollution and habitat-sensitive forms such as caddisflies, stoneflies, and mayflies were common and present in a diversity of forms. A similarly healthy situation still appears to exist in Rattlesnake Creek today.

RECOMMENDATIONS

1. Work toward continued protection of the vegetative buffer zone along the stream corridors.

2. Discourage channelization of each stream. Minimizing channelization allows the streams to retain a natural channel that enhances aquatic habitat.

3. Discourage direct access to the streams by livestock. Large numbers of livestock can trample stream banks, decreasing the ability of streamside vegetation to filter out pollutants and hastening erosion.

4. Evaluate land use to identify significant contributors of nonpoint source pollutants such as livestock waste and eroded soil. Concentrate efforts on the middle Rhodes Creek watershed.

5. Monitor the watershed once again 3-5 years after land treatments are completed to determine how well the program worked to restore water quality. Improved conditions in Rhodes Creek will be associated with the following changes in the benthic community:

    a. An increase in "EPT" animals, especially _Stenonema vicarium_, _Ceratopsyche bifida_, _Chimarra obscura_, and stoneflies. These will make up more than 50% of the benthic community.

    b. A decrease in the proportion of "midges" (below 25% of the benthic community).

    c. An increase in "scraper" animals, especially mayflies in the families Heptageniidae and Baetidae, while the proportion of "filterers" such as _Cheumatopsyche_ decrease.

    d. An increase in "shredder" animals which use leaves and other coarse particulate matter for food. Shredders include certain kinds of stoneflies, craneflies, and isopods.

6. Encourage the Morgan County Health Department to conduct a survey of septic systems within the watershed, especially near the community of Lewisville.

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QUALITY ASSURANCE DUPLICATE VALUES

Metric Values
Rattlesnake Creek Site 1

Sample 1 collected by Greg R. Bright
Sample 2 collected by Greg R. Bright
Samples collected 10/31/96

	Sample 1	Sample 2
Total Genera	19	18
EPT Genera	7	9
Scrapers/Filterers	0.6	1.1
% Dominant Taxon	20	26
EPT/Chironomids	7.5	16
Community Loss Index	0.0	0.3
Hilsenhoff Biotic Index	5.0	4.8
% Shredders	13	2

Site Scores Using Sample 1 as the Reference

	Sample 1	Sample 2
Total Genera	6	6
EPT Genera	6	6
Scrapers/Filterers	6	6
% Dominant Taxon	6	4
EPT/Chironomids	6	6
Community Loss Index	6	6
Hilsenhoff Biotic Index	6	6
% Shredders	6	2
	48	42

Mean Site Score = 45
Each duplicate is within 10% of the mean
Both scores indicate "no impact"

Habitat Scoring Results

	Site 1	Site 2	Site 3	Site 4
SUBSTRATE	10	4	10	14
COVER	12	8	9	10
CHANNEL	15	12	10	14
RIPARIAN	16	5	9	12
POOL/RIFFLE	13	11	10	11
GRADIENT	8	6	10	8
DRAINAGE AREA	9	9	8	6
TOTAL	83	55	66	75

Fish Collections
Mill Creek near Eminence (1942)

Data from Gerking [19]

White sucker
Creek chub
Redfin shiner
Spotfin shiner
Common shiner
Sand shiner
Silverjaw minnow
Bluntnose minnow
Stoneroller
Longear sunfish
White crappie

11 species collected

Fish collections from Rattlesnake Creek - 1979
(TWO SITES)

Data from Gammon et al. [5]

	Site 1	Site 2
Anerican brook lamprey	3	12
Silvery lamprey		4
Grass pickerel	14	2
White sucker	5	5
Northern hogsucker	47	114
Black redhorse	8	109
Golden redhorse		39
Spotfin shiner	4	29
Sand shiner	6	61
Mimic shiner	1	2
Bluntnose minnow	168	109
Bullhead minnow		12
Central stoneroller	46	383
Creek chub	182	91
Blacknose dace	4	
Suckermouth minnow	18	2
Silverjaw minnow	55	95
Striped shiner	192	128
Redfin shiner	19	1
Steelcolor shiner		4
Bigeye chub	31	4
Rockbass	49	60
Green sunfish	4	11
Bluegill	3	8
Longear sunfish	14	104
Orangespotted sunfish		1
Smallmouth bass	3	5
Largemouth bass	4	8
Spotted bass	2	1
Redear sunfish	1	1
Greenside darter	15	9
Johnny darter	49	96
Blackside darter	6	1
Rainbow darter	175	37
Orangethroat darter	22	25
Mottled sculpin	64	40
Creek chubsucker	3	

Total of 37 species

COMMONWEALTH BIOMONITORING
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